New Cloud Networking Enabled by "ProgrammableFlow"

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Abstract

Network virtualization, network programmability, and integration technology of network and computer resource are key technologies for creating and operating a cloud computing. The "ProgrammableFlow" solution, including all required features mentioned above, integrates the network resource and IT resource, hereby enabling implementation of a cloud-oriented data center with more flexibility and lower cost, and enabling the data center to be continuously developed and improved according to the demand of new functions or scale expansion.

Keywords

OpenFlow, network virtualization, programmability, front end, VM migration, data center multi-tenancy, service extension, resource administration, power saving

1. Introduction

The providers of a cloud computing service need to extend and modify their services for a sudden rise in system load or rapid increase/decrease of users, and need to modify and upgrade service components without affecting service continuity. And, they are also expected to control power dissipation of the data center flexibly according to the system load or management policy.

To meet these needs, NEC introduces "ProgrammableFlow" which is a new solution based on OpenFlow technology to achieve the efficient construction and management of data centers for cloud computing.

2. Data Center Issues

A current data center is designed on a complicated configuration where the bandwidth controllers, firewalls (FWs), load balancers (LBs), application servers, storage servers and etc. are connected in multiple stages via L2 switches. The addition of a new server according to service load or the increase of users requires modification of each piece of equipment. For the improvement of server utilization or the reduction of power dissipation, a dynamic migration of virtual machines (VMs) will be required, which may cause more frequent service provisioning. Those requirements usually need high skilled system integration and laborious operation. Moreover, when the data center is operated for a multi-tenant environment, the dynamic service provisioning becomes necessary for each tenant and its management becomes more complicated (**Fig. 1**).

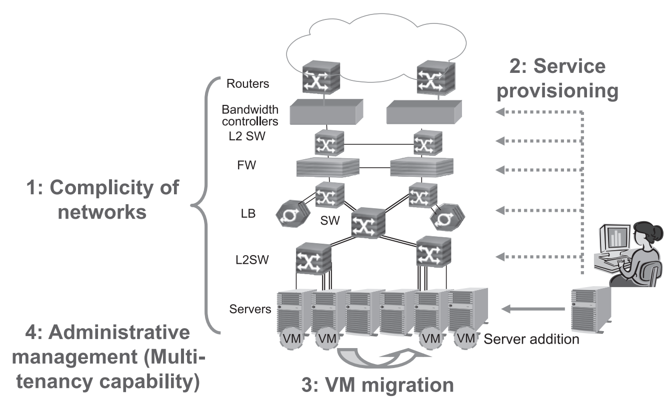

Fig. 1 Issues of data centers.

The OpenFlow technology can solve those various problems about the data center networks.

3. OpenFlow Technology

The Internet is designed based on the TCP/IP protocol for end-to-end communications between terminals and hosts. The routers/switches that transfer the IP traffic are configured in an autonomous, distribution-control architecture. This architecture exchanges topology and routing information among routers/switches using dynamic routing protocols such as RIP/OSPF/BGP. Those routing protocols determine the most appropriate route for the packet transfer in the network.

The OpenFlow [*1] technology enables the programmability of network function by separating the data plane and the control plane which are currently integrated vertically in routers and switches. The OpenFlow technology identifies communications as bundles of "flows" and controls communication on a per-flow basis.

In the OpenFlow architecture, network components are divided into two basic categories. One is switch node (OpenFlow Switch) that transfers packets according to the inside flow table describing the packet transfer route and transfer method per a flow and the other is routing controller (OpenFlow Controller) that decides all routing in network and sets the flow table in each switch.

4. Features of Programmable Flow

"ProgrammableFlow" is the new solution proposed by NEC based on the OpenFlow technology. Traditionally switches and routers decide packet routing by referring the destination MAC address and destination IP address of each received packet and searching the corresponding routing information in the routing table inside switches/routers. The routing information are calculated autonomously and exchanged among other routers/switches through distributed routing protocol. As a result, it has been generally hard to control the packet transfer route from outside, making it also difficult to change the network behavior for other purposes than the shortest path routing.

The ProgrammableFlow solution enables fine control and monitoring of the transfer of each flow. Each flow is defined by any combination of MAC addresses, IP addresses and port numbers in the packet header. The independent management of the routing by OpenFlow controller makes possible the meticulous control of each traffic in the entire network. **Fig. 2** shows the outline of the operations of the ProgrammableFlow solution.

When the switch receives a packet, it searches the flow table by the packet header to determine its route and, when the matching flow entry is found, transfers the packet according to the rule of the matching flow entry. If a matching flow entry is not found, the switch inquires the OpenFlow controller of a new route, receives the reply from the controller, and sets the flow entry into the flow table. The controller can change the flow route anytime just by modifying the flow table in the switch.

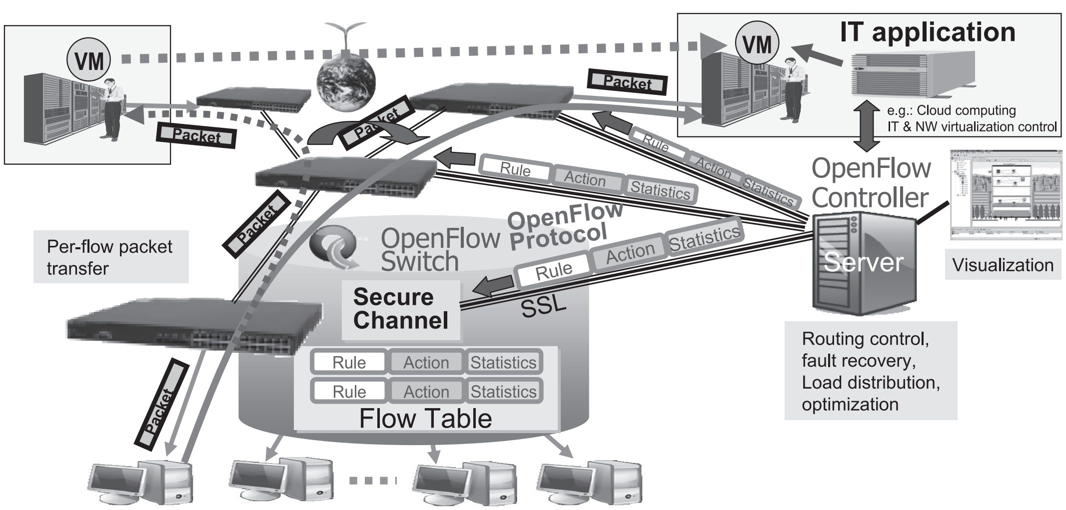

Fig. 2 Outline of ProgrammableFlow operation.

[*1] Consortium established under the leadership of Stanford University, USA. for the Standardization of the interfaces for OpenFlow, such as the APIs.

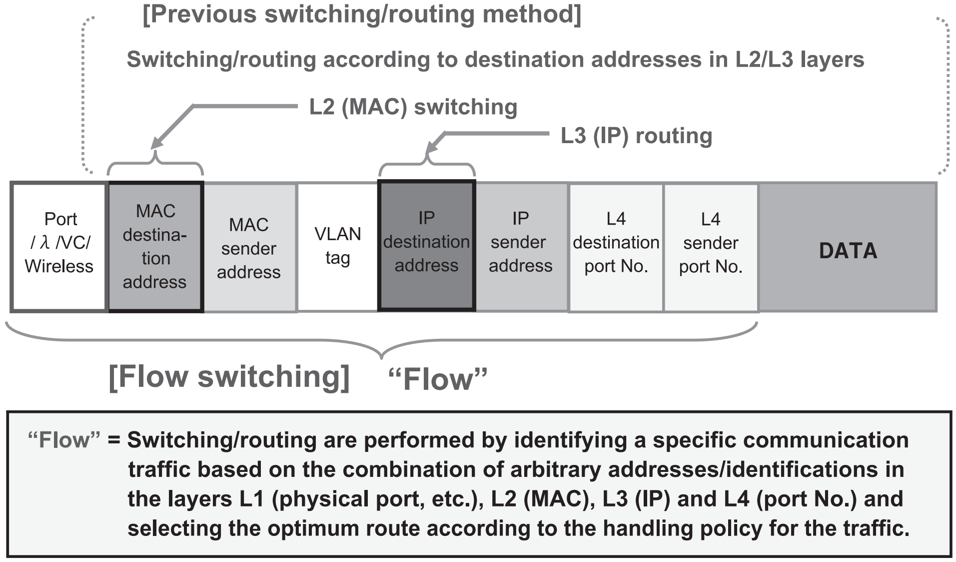

Fig. 3 Flow definition.

As such, the ProgrammableFlow solution enables optimum collaboration between IT and network such as controlling network routes in cooperation with a higher-level application.

Fig. 2 shows an example in which the OpenFlow Controller collaborating with VM migration changes the packet transfer route so that service running on the virtual machine is uninterrupted. And **Fig. 3** shows the definition of the flow.

5. Improvement of Cloud Networking

In this section, we will introduce a ProgrammableFlow-based system solution for a typical cloud data center.

(1) Visualization of Data Center and Improvement of Its Operability

The ProgrammableFlow solution can achieve more fine visualization of servers/network resources in the data center and can thereby improve the overall system availability.

It also makes possible networking configuration setting per a user, such as VLAN and etc., meticulously and easily, which currently require a lot of laborious work. In addition, ProgrammableFlow solution enables optimum traffic transfer per user or per application according to the required SLA of application (**Fig. 4**).

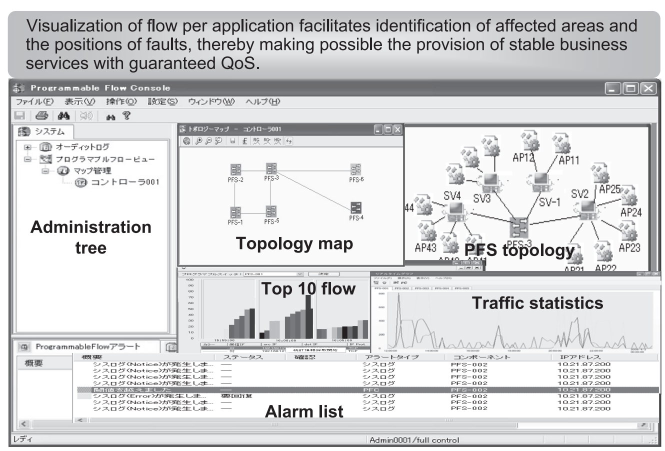

Fig. 4 Visualization of flow.

(2) Dynamic Resource Management

Fig. 5 shows an example of the network configuration of a current data center. Presently, the network in the data center has a complicated configuration where bandwidth controllers, firewalls (FWs) and load balancers (LBs) are connected by multiple stages using L2 switches. The addition of a new server or user requires the change of configuration at each piece of equipment, which results in complex administration of network.

On the other hand, **Fig. 6** shows an example of a configuration when applying the ProgrammableFlow solution to a data center. It consists of a network pool of OpenFlow switches and a server pool including network appliance software, such as user application, firewalls, security, load balancer and etc. The ProgrammableFlow solution can administrate any communication path between user terminals and hosts/VMs for each application. Therefore, it can real-timely grasp overall resource dynamics in data center, and flexibly adapt the overall resource configuration according to the system load, provider's policy, SLA agreements with each user and etc.

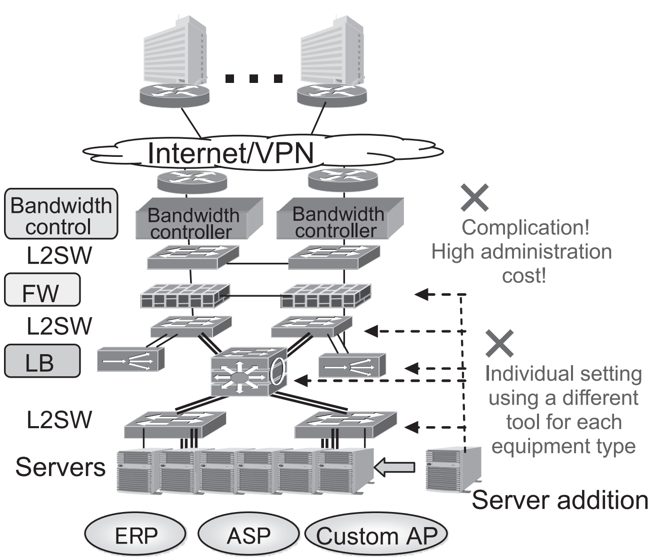

Fig. 5 Current data center configuration.

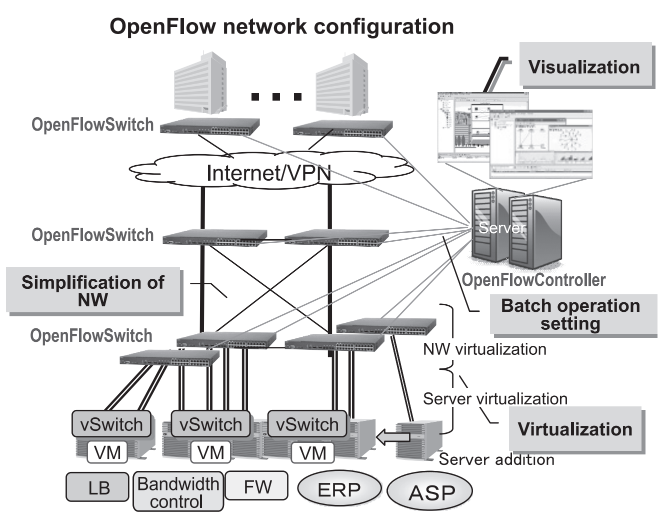

Fig. 6 Next-generation data center configuration based on ProgrammableFlow.

(3) Virtualized Multi-tenancy

Owing to the management of virtualized IT/NW resources in the ProgrammableFlow solution, multi-tenant accommodation can be provided without any physical constraints such as rack positioning or server allotment in each rack. The proposed data center by ProgrammableFlow solution enables providers to construct a multi-tenancy cloud data center, which is free from physical topology constraint. And the providers can dynamically change IT/NW resource assignment to each tenant and can seamlessly expand total system according to its demand (**Fig. 7**).

(4) Power Saving and Non-stop File Updating

More advanced dynamic resource management can be realized by integrating two technologies: one is live VM migration, which moves VMs without interrupting services on VM, and the other is live route change by ProgrammableFlow solution that can switch traffic routes without interrupting communications on the routes (**Fig. 8**).

For example, power saving can be achieved by concentrating servers and network devices with low utilization into designated physical area, making unused servers and network devices detached from active data center, and shutting down their power supply. The same technology also enables on-service upgrade of application and on-service equipment replacement of servers/network devices without interrupting their services, which leads to a large reduction in the administration cost (**Fig. 9**).

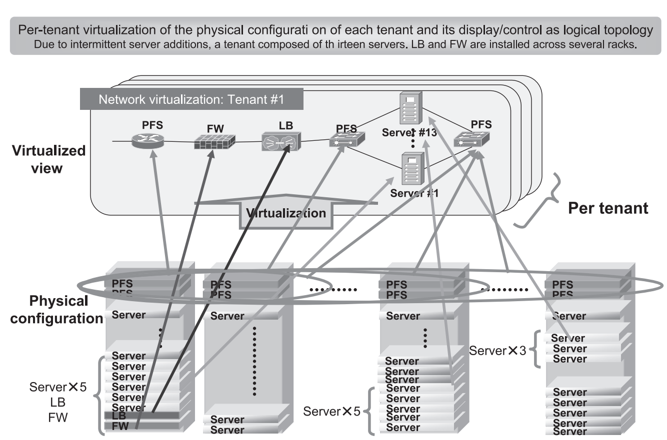

Fig. 7 Virtualized multi tenancy.

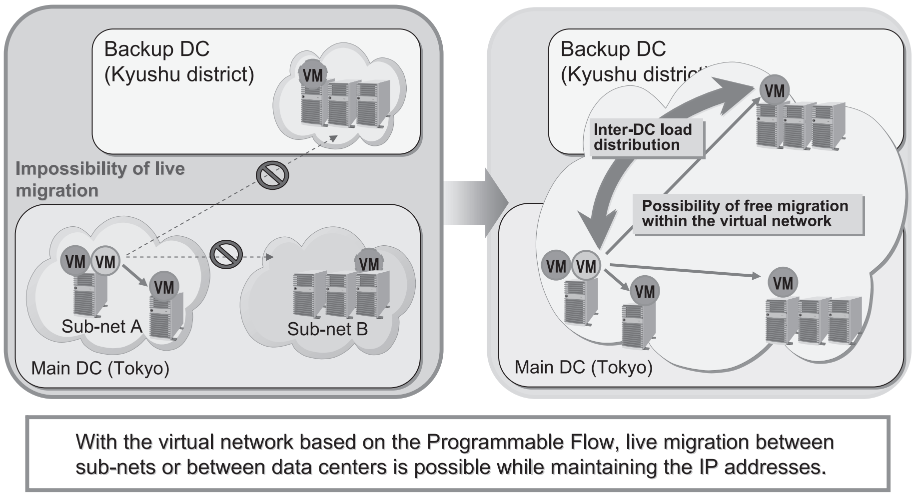

Fig. 8 Live Migration.

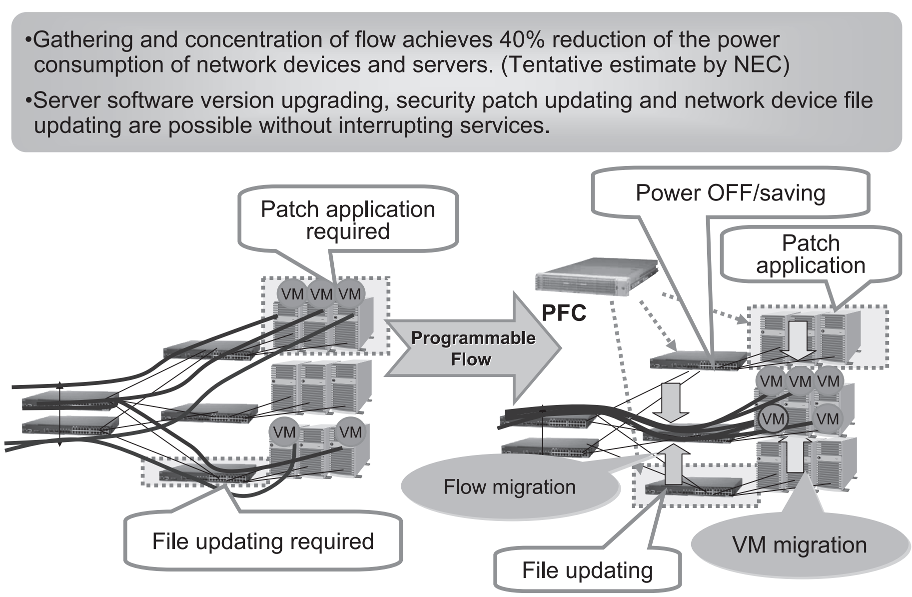

Fig. 9 Power saving and non-stop file updating.

6. Conclusion

We believe that the Internet technology of the next generation can contribute to the cloud computing-oriented infrastructure. NEC will enhance the cloud network by utilizing OpenFlow technology as well as our original network technology asset developed up to the present, and integrating the network technology and IT technology.

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